BOILING COOLER FOR COOLING HEATING ELEMENT BY HEAT TRANSFER WITH BOILING

CROSS REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of Japanese Patent Applications No. 2000-83918 filed on March 24, 2000, No. 2000-214152 filed on July 14, 2000, No. 2000-214204 filed on July 14, 2000, No. 2000-214333 filed on July 14, 2000, and No. 2000-214449 filed on July 14, 2000, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a boiling cooler for cooling a heating element by heat transfer with boiling.

2. Description of the Related Art

JP-A-8-204075 discloses a boiling cooler that cools a heating element by heat transfer with boiling of refrigerant. This boiling cooler can provide a high thermal conductivity in comparison with air-cooling and water-cooling methods. Therefore, it is widely used as a cooler for a semiconductor device that generates a large heat flux. This boiling cooler is composed of a refrigerant tank for storing liquid refrigerant, a radiator for cooling vapor of refrigerant that is boiled in the refrigerant tank by heat generated from the heating element, and a cooling fan for supplying cooling air to the radiator.

In the conventional boiling cooler, however, while condensation heat transfer is performed with a large thermal conductivity at the inside of the radiator, cooling with air is performed with a smaller thermal conductivity at the outside of the radiator. Therefore, the size of the radiator must be increased to comply with the necessity for the cooling with air. As a result, the installation of the boiling cooler is liable to be limited. Especially when the boiling cooler is mounted on a vehicle or the like, its mountability is very low because it must be disposed in a narrow space.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above problems. An object of the present invention is to provide a boiling cooler having good mountability.

According to the present invention, briefly, a boiling cooler has a heat exchange part in which refrigerant vapor performs heat exchange with liquid. The refrigerant vapor is produced from liquid refrigerant that is boiled and gasified by heat transferred from a heating element. In this boiling cooler, the refrigerant vapor can be cooled by the liquid (for example, water) having a thermal conductivity larger than that of air. Therefore, unlike the conventional cooler, a large-sized radiator is not required, and as a result, the size reduction of the boiling cooler can be realized, resulting in good mountability to a vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and features of the present invention will become more readily apparent from a better understanding of the preferred embodiments described below with reference to the following drawings, in which;

FIG. 1A is a cross-sectional view showing a thermal diffusion block, taken along line IA-IA in FIG. 1B, according to a first embodiment of the invention;

FIG. 1B is a plan view showing the thermal diffusion block in the first embodiment;

FIG. 2A is a plan view showing a block body in the first embodiment;

FIG. 2B is a side view of the block body;

FIG. 3A is a plan view showing a state where a lid is attached to the side face of the block body;

FIG. 3B is a side view showing the state shown in FIG. 3A;

FIG. 4 is a diagram showing an entire constitution of a cooling system in the first embodiment;

FIG. 5 is a cross-sectional view showing a thermal diffusion block in a second embodiment of the invention;

FIG. 6 is a cross-sectional view showing a thermal diffusion block in a third embodiment of the invention;

FIG. 7 is a cross-sectional view showing a thermal diffusion block in a fourth embodiment of the invention;

FIG. 8 is a cross-sectional view showing a thermal

diffusion block in a fifth embodiment of the invention;

FIGS. 9A and 9B are cross-sectional views showing a tank chamber in which an inner plate is disposed, in the fifth embodiment;

FIG. 10 is a front view showing a boiling cooler in a sixth embodiment of the invention;

FIG. 11 is a bottom view showing the boiling cooler in the sixth embodiment;

FIG. 12 is a side view showing the boiling cooler in the sixth embodiment;

FIG. 13 is a cross-sectional view taken along line VIII-VIII in FIG. 10;

FIGS. 14A and 14B are cross-sectional views showing a refrigerant vessel in which an inner fin is disposed, in the sixth embodiment;

FIG. 15 is a cross-sectional view taken along line XV-XV in FIG. 12;

FIG. 16 is a cross-sectional view taken along line XVI-XVI in FIG. 12;

FIG. 17 is a cross-sectional view taken along line XVII-XVII in FIG. 12;

FIG. 18 is a cross-sectional view taken along line XVIII-XVIII in FIG. 12;

FIG. 19 is a diagram showing a cooling water circuit of a water-cooling system in the sixth embodiment;

FIG. 20 is a cross-sectional view taken along line XX-XX in FIG. 18;

FIG. 21 is a front view showing the boiling cooler with the refrigerant vessel that is inclined, in the sixth embodiment;

FIG. 22 is a cross-sectional view taken along line XXII-XXII in FIG. 18;

FIG. 23 is a front view showing a boiling cooler in a seventh embodiment of the invention;

FIG. 24 is a cross-sectional view taken along line XXIV-XXIV in FIG. 23;

FIG. 25 is a cross-sectional view taken along line XXV-XXV in FIG. 24;

FIGS. 26A and 26B are upside views showing modifications of the boiling cooler in the seventh embodiment;

FIG. 27 is a front view showing a boiling cooler according to an eight embodiment of the invention;

FIG. 28 is a bottom view showing the boiling cooler of FIG. 27;

FIG. 29 is a side view showing the boiling cooler of FIG. 27;

FIG. 30 is a cross-sectional view taken along line XXX-XXX in FIG. 29;

FIG. 31 is a cross-sectional view taken along line XXXI-XXXI in FIG. 30;

FIG. 32 is a cross-sectional view taken along line XXXII-XXXII in FIG. 27;

FIG. 33 is a cross-sectional view taken along line

XXXIII-XXXIII in FIG. 29;

FIG. 34 is a cross-sectional view taken along line XXXIV-XXXIV in FIG. 29;

FIG. 35 is a cross-sectional view taken along line XXXV-XXXV in FIG. 29;

FIG. 36 is a front view showing a boiling cooler according to a ninth embodiment of the invention;

FIG. 37 is a cross-sectional view showing a refrigerant flow control member of the boiling cooler in the ninth embodiment;

FIG. 38 is a front view showing a boiling cooler according to a tenth embodiment of the invention; and

FIG. 39 is a cross-sectional view showing a refrigerant flow control member of the boiling cooler in the tenth embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

(First Embodiment)

A boiling cooler in a first embodiment of the invention, an entire cooling system of which is shown in FIG. 4, has a box-shaped thermal diffusion block 1 enclosing refrigerant therein.

As shown in FIGS. 1A and 1B, the thermal diffusion block 1 is composed of a block body 2, two side plates 3 (FIG. 3) closing opening portions of the block body 2 opening at both side faces thereof, an upper lid 4 fixed to an upper end face of the block body 2, and outer plates 5

fixed to the both side faces of the block body 2. As shown in FIGS. 2A and 2B, the block body 2 has a hollow shape, an upper wall of which has a convexo-concave shape (at an upper portion in a vertical direction in FIG. 2B) having protruding convex portions (concave portions) that extend in parallel with a vertical direction in FIG. 2A to penetrate the inside of the block body 2.

Sealing faces 6, one of which is shown in FIG. 2B, are provided at the upper and lower side faces of the block body 2 in FIG. 2A, and the side plates 3 are attached to the sealing faces 6 to close the opening portions. Each sealing face 6 is formed to be lower than each side face of the block body 2 by an amount corresponding to the thickness of each side plate 3. Each side plate 3 is, as shown in FIG. 3B, formed into a shape corresponding to that of the opening portion opening at the side face of the block body, and closes the opening portion by abutting the sealing face 6.

The upper lid 4 has a plan shape a size of which is identical with that of the block body 2, and as shown in FIG. 1A, is fixed to the end face of the block body 2 with a sealing member 7 interposed therebetween by bolts 8 provided at the right and left sides of the block body 2. The outer plates 5 are, as shown in FIG. 1B, externally fixed to the both side faces of the block body 2 with a sealing member 9 interposed therebetween by bolts 10. The fixation of the outer plates 5 is performed after the upper lid 4 is fixed to the block body 2. Each of the two outer plates 5 has a

water communication hole 11 on which a pipe join port 11a is provided.

The thermal diffusion block 1 defines a tank chamber 12 sealed by the two side plates 3 closing the hollow portion defined inside the block body 2. A specific amount of refrigerant is enclosed in the tank chamber 12 after deaeration. As shown in FIG. 1A, the tank chamber 12 is composed of a refrigerant chamber 12a and a radiation space (vapor passages) 12b. The refrigerant chamber 12a extends widely in the lateral direction and in the direction perpendicular to the paper space in the figure, with a narrow width (height) in the vertical direction. The radiation space 12b is composed of plural protruding portions protruding upward from the refrigerant chamber 12a. The refrigerant chamber 12a is filled with liquid refrigerant almost at an entire height thereof.

On the other hand, as shown in FIG. 1A, a heating element 13 is fixed to the bottom face of the thermal diffusion block 1 (bottom outer wall of the block body 2), so that heat is transferred from the heating element 13 to liquid refrigerant in the tank chamber 12 via the bottom face of the block body 12. In the thermal diffusion block 1, a water passage portion 15 is provided with a hollow portion that is defined between the convexo-concave portions of the block body 2 and the upper lid 4, and is closed with the two outer plates 5. As shown in FIG. 4, the water passage portion 15 is connected to a cooling water circuit 17

through a water pipe 16 connected to the pipe joint ports 11a provided at the outside of the outer plates 5. The cooling water circuit 17 has a pump 18 for circulating cooling water, and a radiator 19 for cooling the cooling water with air.

Next, an operation of the boiling cooler in the first embodiment is explained below.

Liquid refrigerant in the refrigerant chamber 12a is boiled and gasified by heat transferred from the heating element 13 through the bottom face of the refrigerant chamber 12a, and then flows, as refrigerant vapor, into the radiation space 12b of the tank chamber 12. On the other hand, cooling water flows into the water passage portion 15 of the thermal diffusion block 1 by the operation of the pump 18. Accordingly, refrigerant vapor in the radiation space 12b is cooled by cooling water flowing in the water passage portion 15, and is condensed to produce liquid drops (condensate) on the inner wall of the tank chamber 12 defining the radiation space 12b. The liquid drops drip into the refrigerant chamber 12a and return to a part of liquid refrigerant. Cooling water that has received heat from refrigerant vapor has a raised temperature, radiate heat into atmosphere in the radiator 19 to have a lowered temperature, and then returns to the water passage portion 15 again.

The advantages of the first embodiment are as follows.

The thermal diffusion block 1 of the first embodiment

is so constructed that refrigerant vapor, which is boiled by heat from the heating element 13 to gasify, is condensed by cooling water. This structure is suitable for cooling the heating element 3 composed of a semiconductor device capable of generating a large thermal flux. A large-sized radiator is not required in comparison with the above-mentioned conventional radiator, resulting in size reduction of the boiling cooler. The limitation for installing the boiling cooler is small, and for example, its mountability to a vehicle having a limited space can be improved significantly. The thermal diffusion block 1 needs not be integrated with the radiator 19, and may be disposed separately from the radiator 19 as shown in FIG. 4.

Further, in the thermal diffusion block 1 of the present embodiment, heat exchange between refrigerant vapor and cooling water (coolant) is performed through the boundary face (wall) between the tank chamber 12 and the water passage portion 15. That is, the boundary face constitutes a heat transfer face. Therefore, the boundary face formed into the convexo-concave shape can increase a heat transfer area (radiation area). Further, liquid face fluctuation of refrigerant in the tank chamber 12, which can be caused by inclination of the thermal diffusion block 1, can be lessened in comparison with a case where the boundary face between the tank chamber 12 and the water passage portion 15 is flat. Therefore, the radiation performance can be suppressed from deteriorating due to the liquid face

fluctuation.

(Second Embodiment)

FIG. 5 shows a cross-section of a thermal diffusion block 1a according to a second embodiment, which corresponds to that shown in FIG. 1A in the first embodiment. In this and following embodiments, the same parts as those shown and explained in the first embodiment are designated with the same reference numerals.

In the thermal expansion diffusion block 1a of this embodiment, thickness t of the bottom wall of the block body 2, i.e., between the bottom face of the refrigerant chamber 12a and the outer bottom face of the block body 2 to which the heating element 13 is fixed, is thinned except for portions 20 where screw holes for the bolts 14 are formed. In this case, in comparison with the first embodiment, heat from the heating element 13 is efficiently transferred to liquid refrigerant in the refrigerant chamber 12a, so that heat transfer with boiling of refrigerant can be performed efficiently. As a result, the radiation performance is improved.

(Third Embodiment)

FIG. 6 shows a cross-section of a thermal diffusion block 1b according to a third embodiment of the invention, which corresponds to that shown in FIG. 1A in the first embodiment. The thermal diffusion block 1b has radiation fins 21 disposed in the water passage portion 15, in addition to the constitution of the second embodiment. The

radiation fins 21 are made of aluminum, and as shown in FIG. 6, each radiation fin is inserted into a concave portion (space) defined between neighboring two protruding portions 2a of the block body 2 and is brazed to the outer walls of the protruding portions 2a. Because the radiation fins 21 increase the heat transfer area (radiation area), the radiation performance is improved.

(Fourth Embodiment)

FIG. 7 shows a cross-section of a thermal diffusion block 1c according to a fourth embodiment, which corresponds to that shown in FIG. 1A in the first embodiment. In the thermal diffusion block 1c in this embodiment, the height of the protruding portions 2a of the block body 2 is the largest at the generally central portion in the lateral direction of the tank chamber 12 (in the direction perpendicular to the paper space of the figure), and is gradually decreased toward the both sides in the lateral direction of the tank chamber 12.

In this constitution, for example, if the thermal diffusion block 1c is mounted on a vehicle and is inclined when the vehicle travels, the amount of refrigerant enclosed in the protruding portions 2a (radiation space 12b) becomes small as compared to the cases in the first to third embodiments because the height of the protruding portions 2a is small at the both sides in the lateral direction of the tank chamber 12. As a result, the liquid face fluctuation can be suppressed when the thermal diffusion block 1c is

inclined. The bottom surface of the refrigerant chamber 12 where refrigerant boils can be easily prevented from being exposed, i.e., from being uncovered by refrigerant, so that the radiation performance required for cooling the heating element 13 can be maintained appropriately.

(Fifth Embodiment)

FIG. 8 shows a cross-section of a thermal diffusion block 1d according to a fifth embodiment of the invention, which corresponds to that shown in FIG. 1A in the first embodiment. The thermal diffusion block 1d in this embodiment has inner plates 22 disposed in the refrigerant chamber 12a. The inner plates 22 are made of, for example, metallic plate such as aluminum having sufficient thermal conductivity. Each inner plate 22 is, as shown in FIGS. 9A and 9B, held by being inserted into groove portions 12c formed on the wall surface of the refrigerant chamber 12a. As shown in FIGS. 9A and 9B, the inner plate 22 can have notch portions 22a at either side thereof. The inner plates 22 disposed in the refrigerant chamber 12a can increase a boiling area in the refrigerant chamber 12a to improve the refrigerant performance.

(Sixth Embodiment)

FIGS. 10 to 12 shows a contour of a boiling cooler 30 in a sixth embodiment of the invention. FIG. 10 is a front view of the boiling cooler 30, FIG. 11 is its bottom view (plan view from a side of an attachment face of a heating element), and FIG. 12 is a side view (plan view from a side

face of a radiating portion).

The boiling cooler 30 in this embodiment is, for example, mounted on an electric vehicle to cool an IGBT module (heating element 31) constituting an inverter circuit for a vehicular motor. As shown in FIGS. 10 to 12, the boiling cooler 30 is composed of a refrigerant vessel (tank) 32 for storing liquid refrigerant therein, and radiators 33 for cooling vapor of refrigerant that is boiled upon receiving heat from the heating element 31, which are made of metallic materials (for example, aluminum) having sufficient thermal conductivity.

The refrigerant vessel 32 is a thin hollow member having a small thickness (height) in the vertical direction and a large dimension in the horizontal direction (lateral and longitudinal directions). Both ends of the refrigerant vessel 32 in the longitudinal direction are open and its inside is divided into several passage portions.

Referring to FIG. 13, inner fins 34 are inserted into at least some of the passage portions (vapor outflow passages 32a) contained in the region (boiling portion) to which the heating element 31 is attached. Each inner fin 34 is, as shown in FIGS. 14A and 14B, formed with plural recess portions 34a to increase a heat transfer area (boiling area). The location of the inner fin 34 is determined by grooves 32d formed on the inner wall of the refrigerant vessel 32 into which the inner fin 34 is inserted. The heating element 31 is closely attached to the lower side outer surface of

the refrigerant vessel 32, and is fixed thereto by bolts 35.

Referring to FIG. 10, the radiators 33 are respectively composed of a pair of tanks (lower tank 36 and upper tank 37) and a heat exchange part (described below), and are provided at the both sides (right and left sides) of the refrigerant vessel 32 in the lateral direction. The lower tank 36 is provided to communicate with the passage portions of the refrigerant vessel 32, and stores liquid refrigerant in cooperation with the refrigerant vessel 32. Therefore, the right side radiator 33 and the left side radiator 33 communicate with each other through the refrigerant vessel (passage portions) 32 at the respective lower tanks 36. Vapor of refrigerant boiled in the refrigerant vessel 32 flows in the right and left directions in the vapor outflow passages 32a and enters the lower tanks 36. On the other hand, as shown in FIG. 13, liquid refrigerant is held with a liquid surface, a position of which is higher than the upper surface of the refrigerant vessel 32. That is, the inside of the refrigerant vessel 32 is filled with liquid refrigerant.

Referring to FIGS. 13 and 18, each of the lower tank 36 holds a refrigerant flow control plate 38 therein. The refrigerant flow control plate 38 forms an extension passage portion 38a for extending the vapor outflow passages 32a into the lower tank 36 to prevent, in the lower tank 36, interference between refrigerant vapor coming out of the vapor outflow passages 32a and condensate returned from the

radiator 33 (FIG. 20). Each upper tank 37 is positioned above the heat exchange part, and faces the lower tank 36 through the heat exchange part interposed therebetween in the vertical direction.

The heat exchange part is, as shown in FIG. 13, composed of plural radiation passages 39 connecting the lower tank 36 and the upper tank 37, and water jackets 40 provided around the radiation passages 39. Heat exchange is performed between refrigerant vapor flowing in the radiation passages 39 and cooling water flowing in the water jackets 40. The radiation passages 39 respectively have an elongated rectangular opening in cross-section, and are arranged with an approximately constant interval in the width direction of the tanks 36, 37 (lateral direction in FIG. 15).

Referring to FIG. 16, an inner fin 41 is inserted into an inside of each radiation passage 39. The inner fin 41 is, for example, formed from a thin metallic (such as aluminum) plate bent into a corrugated shape with a given pitch. The inner fin 14 is biased toward one side (in the right direction in FIG. 16) in the radiation passage 39. Accordingly, the inside of the radiation passage 39 is divided into a first passage portion (vapor passage portion 39a) defined at the other side of the inner fin 41 (at the outside of the inner fin 41), and a second passage portion (liquid passage portion 39b) including plural passages defined by the inner fin 41 at the given pitch.

The water jackets 40 constitute passages in which

cooling water flows. The water jackets 40 surround the peripheries of the respective radiation passages 39 and the entire periphery of the heat exchange part. The water jackets 40 are further connected to the cooling water circuit in which cooling water circulates. The cooling water circuit is, as shown in FIG. 19, used for a cooling system for cooling with water a motor 42 for moving an electric vehicle, and has a pump 43 for circulating cooling water and a radiator 44 for cooling the cooling water with air.

Next, the operation of the present embodiment is explained below.

Liquid refrigerant stored in the refrigerant vessel 32 boils upon receiving heat from the heating element 31, and as shown in FIG. 20, flows from the vapor outflow passages 32a into the lower tank 36 through the extension passage portion 38a. After that, refrigerant vapor flows from the lower tank 36 into the vapor passage portions 39a in the radiation passages 39, rises in the vapor passage portions 39a, and flows into the upper tank 37. It further flows from the upper tank 37 into the liquid passage portions 39b defined by the inner fin 41 at the specific pitch. The refrigerant vapor entering the liquid passage portions 39b is cooled by cooling water flowing in the water jackets 40, and is condensed and liquefied on the surfaces of the inner fins 42 and on the inner walls of the radiation passages 39.

Condensate liquefied in the liquid passage portions 39b is collected and held at the lower portion of the inner

fin 41 due to a surface tension, and as shown in FIG. 16, forms a liquid part at the lower portion of the inner fin 41. This liquid part prevents refrigerant vapor from entering the liquid passage portions 39b from the lower tank 36 directly, and contributes to form a refrigerant circulating flow in the radiation passages 39 desirably. The condensate collected in the liquid part drops sequentially into the lower tank 36 from the liquid part due to a pressure of refrigerant vapor rising in the vapor passage portions 39a.

For example, this boiling cooler 30 is mounted on the electric vehicle so that the longitudinal direction of the refrigerant vessel 32 (lateral direction in FIG. 10) is parallel to the front and rear direction of the vehicle and to the horizontal direction. In this case, when the vehicle travels on a slope, the refrigerant vessel 32 may be inclined with respect to the horizontal plane. Specifically, as shown in FIG. 21, the refrigerant vessel 32 may be inclined with the right side higher than the left side thereof.

In this case, refrigerant vapor produced by the boiling therein rises (moves toward the right side) along the inclined refrigerant vessel 32, and flows into the lower tank 36 of the right side radiator 33. After that, as mentioned above, condensate cooled in the radiator 33 drops in the lower tank 36. At that time, condensate dropped from the liquid part into the lower tank 36 mainly enters, from both outer sides of the refrigerant control plate 38, a

passage portion (liquid return passage) 32b of the refrigerant vessel 32 (FIGS. 18 and 22). The condensate entering the liquid return passage 32b then flows in the inclined refrigerant vessel 32, enters the lower tank 36 of the left side radiator 33, and then returns to the boiling portion in the refrigerant vessel 32 from the lower tank 36 again.

The boiling cooler 30 in the sixth embodiment has a structure different from those of the thermal radiation blocks explained in the first to fifth embodiments; however, it is the same as those in the point that vapor of refrigerant, which is boiled and gasified upon receiving heat from the heating element 31, is cooled by water. Therefore, the boiling cooler 30 is also suitable for cooling the heating element 31 including a semiconductor device and the like having a large thermal flux.

Also, because the radiators 33 are provided at the both sides of the refrigerant vessel 32, at least one of the radiators 33 performs heat exchange between refrigerant vapor and cooling water if there arises a positional difference in height between the two radiators 33. As a result, a stable radiation performance can be attained without being lessened. Especially when the boiling cooler 30 is mounted on a vehicle, this boiling cooler 30 is very effective because the radiation performance can be exhibited stably even if the radiation vessel 32 is inclined to either side by the vehicle traveling on a slope or the like.

(Seventh Embodiment)

A boiling cooler 30a according to a seventh embodiment of the invention is a modification of the boiling cooler 30 in the sixth embodiment, and is explained with reference to FIGS. 23 to 25. In this and following embodiments, the same parts as those in the sixth embodiment are designated with the same reference numerals.

The boiling cooler 30a in this embodiment has a refrigerant vessel 32 with an upper wall 32c that constitutes an upper surface of the passage portion. As shown in FIGS. 23 and 25, the upper wall 32c is bowed inward, and gently inclined upward from the central portion to both sides in the longitudinal direction (lateral direction in FIG. 25). Therefore, the vertical width of the passage portion is minimum at the central portion, and is increased gradually toward the outlet sides. The other features are substantially the same as those in the sixth embodiment.

According to the boiling cooler 30a in the seventh embodiment, the upper wall 32c of the refrigerant vessel 32 is bowed inward, and is gently inclined upward from the central portion toward the both sides in the longitudinal direction thereof. Therefore, even when the refrigerant vessel 32 is disposed generally horizontally, refrigerant vapor produced in the refrigerant vessel 32 easily flows toward the outlet sides of the vapor outflow passages 32a along the inclined (bowed) upper wall 32c. As a result, refrigerant vapor kept remaining in the refrigerant vessel

32 is decreased (or eliminated), and refrigerant vapor can flow into the radiators 33 smoothly. The radiators 33 can be utilized effectively, and the radiation performance can be exhibited stably.

Refrigerant vapor produced at the boiling portion flows toward the right and left sides in the vapor outflow passages 32a defined by the upper wall 32c that is low at the central portion and is heightened towards the outlet sides. Because of this, the amount of refrigerant vapor is increased gradually from the central portion toward the outlet sides in the refrigerant outflow passages 32. The vertical width of the refrigerant vessel 32 (passage portion) is set to be the smallest at the central portion and to be gradually increased (widened) toward the outlet sides in the longitudinal direction thereof. Thus, the passage width is set in accordance with the amount of refrigerant vapor. In consequence, the amount of refrigerant can be reduced without lessening the radiation performance, and cost reduction can be achieved by the reduced amount of refrigerant.

In the above-mentioned embodiments, the radiators 33 are provided at the both sides of the refrigerant vessel 32; however, as shown in FIGS. 26A and 26B, a looped (for example, annular) radiator 33 may be provided on an entire circumference of the refrigerant vessel 32. In this case, preferably, the vapor outflow passage in the refrigerant vessel 32 is open at the entire circumference of the

refrigerant vessel 32. The radiators 33 have a water-cooling structure with the water jackets 40; however, they may have an air-cooling structure in which refrigerant vapor is cooled by outside air.

(Eighth Embodiment)

Next, an eighth embodiment of the invention is explained referring to FIGS. 27 to 35, in which the same parts as those in the sixth embodiment are designated with the same reference numerals. A boiling cooler 30b in this embodiment has a refrigerant flow control member described below in addition to the refrigerant vessel 32 and the radiators 33 for cooling vapor of refrigerant boiled upon receiving heat from the heat element 31.

The refrigerant flow control member is, as shown in FIG. 27, provided inside the lower tank 36, and is, as shown in FIG. 30, composed of a control plate 50 generally horizontally disposed in the lower tank 36 and communication ports 51 (51a, 51b) penetrating the control plate 50. As shown in FIG. 31, the inside of the lower tank 36 is divided by the control plate 50 into an upper space (space at the side of the radiator 33) and a lower space (space at the side of the refrigerant vessel 32), and the upper space and the lower space communicate with each other through the communication ports 51 refrigerant vapor and condensate pass through.

The communication ports 51 are composed of first communication ports 51a cylindrically projecting from the

upper surface of the control plate 50 into the upper space and opening at a higher position than the upper surface of the control plate 50, and second communication ports 51b cylindrically projecting from the lower surface of the control plate 50 into the lower space and opening at a lower position than the lower surface of the control plate 50. The first communication ports 51a and the second communication ports 51b are, as shown in FIG. 30, alternately provided at a given pitch in the lateral direction and in the longitudinal direction of the control plate 50. Each first communication port 51a has an opening area larger than that of each second communication port 51b. The other features are substantially the same as those in the sixth embodiment. Incidentally, FIG. 34 shows arrangement of an inner fin 41 in a radiation passage 39, which is different from that shown in FIG. 16 in the sixth embodiment; however, the inner fin 41 may be arranged in the radiation passage 39 as shown in FIG. 16 in this embodiment.

Next, an operation in this embodiment is explained.

Liquid refrigerant stored in the refrigerant vessel 32 is boiled by heat from the heating element 31 to produce refrigerant vapor, and refrigerant vapor flows into the lower space of the lower tank 36 through the passage portions 32a. In the lower space, it is difficult for refrigerant vapor to flow into the second communication ports 51b because the second communication ports 51b cylindrically project downward from the lower surface of the

control plate 50. Therefore, refrigerant vapor mainly flows into the cylindrical first communication ports 51a, and enters the upper space of the lower tank 36. After that, refrigerant vapor flows in the radiation passages 39 in the heat exchange part in which it is cooled by cooling water flowing in the water jackets 40 to be condensed and liquefied on the surface of the inner fins 41 and on the inner walls of the radiation passages 39.

Most liquefied condensate drops onto the upper surface of the control plate 50 from the radiation passages 39, and a part of the condensate drops directly into the communication ports 51 (mainly the second communication ports 51b because refrigerant vapor is blowing up from the first communication ports 51a in this case) to be dropped into the lower space of the lower tank 36. The condensate dropped onto the upper surface of the control plate 50 is finally conducted into the lower space of the lower tank 36 through the second communication ports 51b, and returns to the boiling portion in the refrigerant vessel 32.

As mentioned above, the refrigerant flow control member in this embodiment has the first communication ports 51a cylindrically projecting from the control plate 50 into the upper space to open at the position higher than the upper surface of the control plate 50, and the second communication ports 51b cylindrically projection from the control plate 50 into the lower space to open at the position lower than the lower surface of the control plate

50. In addition, the opening area of each second communication port 51b is smaller than that of each first communication port 51a. Therefore, when refrigerant vapor passes through the first or second communication ports 51a, 51b to enter the upper space in the lower tank 36, it mainly flows into the first communication ports 51a to enter the lower space because the flow resistance of the second communication ports 51b is large in comparison with that of the first communication ports 51a.

Also, condensate liquefied in the heat exchange part drops onto the upper surface of the control plate 50, and flows into the lower space of the lower tank 36 not through the first communication ports 51a opening at the position higher than the upper surface of the control plate 50, but through the second communication ports 51b.

As a result, refrigerant vapor flow and condensate flow can be separated from each other when they passes through the communication ports 51 of the control plate 50, so that interference between refrigerant vapor and condensate can be suppressed and refrigerant can circulate efficiently. Further, because the first communication ports 51a in which refrigerant vapor is liable to flow have the opening area larger than that of the second communication ports 51b in which condensate is liable to flow, the refrigerant vapor flow and the condensate flow can be controlled more efficiently. The other advantages are substantially the same as those in the above-mentioned

embodiments.

(Ninth Embodiment)

FIG. 36 is a front view showing a boiling cooler 30c according to a ninth embodiment of the invention. The boiling cooler 30c is different from the boiling cooler 30b shown in FIG. 27 in the structure of the refrigerant flow control member. In this embodiment, as shown in FIG. 37, the first communication ports 51a are open on the upper surface of the control plate 50, and the second communication ports 51b cylindrically protrude from the lower surface control plate 50 downward and open at a position lower than that of the lower surface of the control plate 50.

According to this constitution, similarly to the eighth embodiment, refrigerant vapor produced in the refrigerant vessel 32 is liable to pass through the first communication ports 51a, having smaller resistance than that of the second communication ports 51b, so as to enter the upper space of the lower tank 36. Therefore, condensate is liable to flow in the second communication port 51b while avoiding the first communication ports 51a from which refrigerant vapor is blowing up. In consequence, refrigerant vapor flow and condensate flow can be separated from each other and refrigerant can circulate efficiently.

(Tenth Embodiment)

FIG. 38 is a front view showing a boiling cooler 30d according to a tenth embodiment of the invention. The refrigerant flow control member in this embodiment has, as

shown in FIG. 39, first communication ports 51a that cylindrically project from the upper surface of the control plate 50 to open at a position higher than the upper surface of the control plate 50, and second communication ports 51b that are open on the lower surface of the control plate 50.

According to this constitution, like the eighth embodiment, condensate liquefied in the radiator drops on the surface of the control plate 50, and then flows into the second communication ports 51b to be conducted into the lower space of the lower tank 36. The condensate does not flow into the first communication ports 51a that open at the higher position than the surface of the control plate 50. Therefore, refrigerant vapor produced in the refrigerant vessel 32 can mainly flow into the first communication ports 51a to enter the upper space at the radiation side. In consequence, refrigerant vapor flow and condensate flow can be separated from each other without interference therebetween, and refrigerant can circulate efficiently.

The boiling coolers described in the above-mentioned embodiments are not used only for vehicles, but may be used for any transportation means such as ships (especially small-size ship capable of being swung largely) and helicopters. Otherwise, it may be used on a slope.

While the present invention has been shown and described with reference to the foregoing preferred embodiments, it will be apparent to those skilled in the art that changes in form and detail may be made therein without

departing from the scope of the invention as defined in the appended claims.